NASA CubeSat/SmallSat Reference Model

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PHM Technology
Decisions better made

Objectives

- Enabling Mission Success and effective design improvements
- Identify Risk (safety, performance, availability, failure) for mitigation
- Ensuring safety through hazard identification and control verification
- Preventing investments from becoming debris
- Optimizing monitoring for preventative action and fault prevention

Benefits of Model-based Approach

- Automated analyses and reporting
- Analyst agnostic analyses
- Fault simulation and impact visualization
- Efficient, consistent, thorough and accurate
- Knowledge digitization (enables re-use)
- Traceability of analyses and model changes

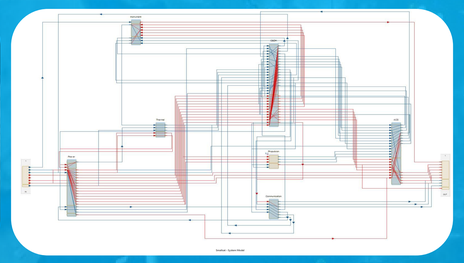
CubeSat/SmallSat Model Configuration

The CubeSat/SmallSat Reference model configuration is shown here – it is derived from an actual NASA small satellite mission model.

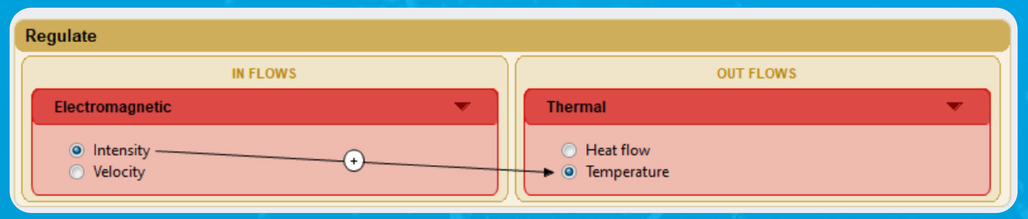
Red lines represent energy flow (hydraulic pressure, electric voltage etc).

Blue lines represent data flow (discrete amplitude, continuous data etc).

Each block has functions and flows defined from a fixed taxonomy and are hierarchical.

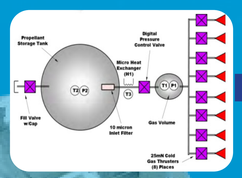


Functions and Flows

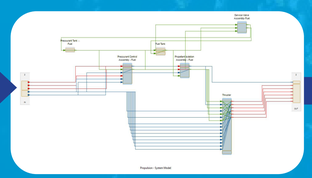


Functions and flows are used to describe the inputs and outputs of a block in the system.
A causal relationship is represented via the connecting arrow between the inputs and outputs which drives the propagation of potential failures in the system given a component failure.
By identifying potential propagation of failures within the system, it allows for planning of mitigating risk and successful operation of the CubeSat/SmallSat.

How to create a MADe model – Propulsion System



System Schematic



MADe Model

Physical System

MADe fits in the product life-cycle in the design phase but can also be used for legacy systems (i.e., systems already in operation). The system concept will be developed and iterated within MADe using blocks, functions and flows to arrive at a final design supported by the different analyses (such as Fault Tree, FMEA, Reliability etc) available in the software.

Mission Assurance

Reliability in MADe is assessed in multiple ways (prediction, fault trees, failure mode analysis, maintainability and availability). If component reliability is known, it can be entered as an MTTF or Part Failure Rate for Exponential Distribution type Reliability or Slope and Characteristic Life for Weibull Distribution type Reliability. In the case where system components are not yet selected from a vendor (i.e., design phase), it is possible to set target reliability values in MADe to determine the required reliability for each component. The values are used in Reliability Block Diagrams to support design trade studies and assess system reliability, and used in fault trees to assess scenario risks. In failure mode analysis, reliability is used to find the likelihood of critical failure points. They are also used in availability and maintainability analyses to develop sufficient operational and support plans.

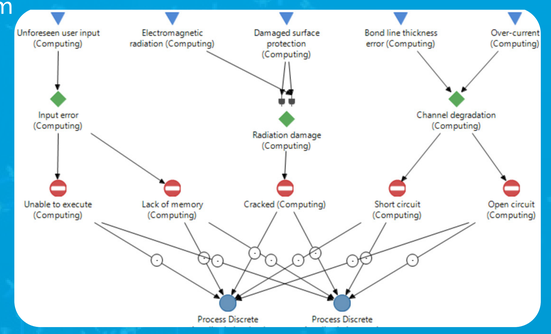
Safety in MADe is assessed by modelling the hazards and inhibits. The fault-injection simulation capability can then be used to assess the robustness and independence of safety features.

Quality Assurance is assisted with the system models for insights and dependencies. The fault-injection simulation capability can then be utilized to see the impact of non-compliant or suspect implementations. Further with the integration of requirements quality verifications can be tracked and kept current for all disciplines.

Software Assurance is supported in the same way as hardware assurance.

Physical Failures

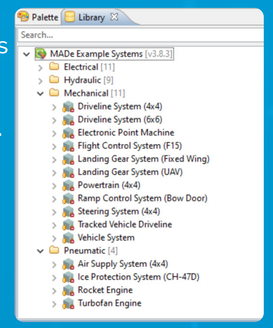
System blocks contain failure information in the form of a failure diagram.
A failure diagram is a tree-like structure which describes the cause, mechanism and fault which leads to a functional failure.
Causes are represented by:
Mechanisms are represented by:
Faults are represented by:
Failure diagrams can be populated by a fixed taxonomy in MADe to capture knowledge of previous CubeSat system contributors.
Safety and Risk reporting and analyses use these diagrams for consistent and repeatable results.



MADe Library & Palette - Repeatable & Consistent Models

System models of CubeSat/SmallSats can be reused and recycled through the MADe library. Users can save models of specific components, subsystems or systems to the library to share between projects to ensure consistent models and analysis outputs. The items which are saved to the library also contain their model information such as reliability values, functions and flows. Failure information from failure diagrams are also stored on an item saved to the library – this is an advantage as it provides consistent failure information across projects, which may see analysts change over time.

MADe also contains a palette of common components across multiple disciplines – this allows for users to build models quickly and consistently. These have pre-defined functions and flows, as well as failure diagrams containing common modes of failure.



Want to use the NASA-GSFC SmallSat reference model for your next project? Leave your academic email address and name or contact us!

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